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INFORMATION CIRCULAR

CONTROL OF ROOF AND PREVENTION OF ACCIDENTS FROM FALLS OF ROCK AND COAL

SUGGESTED ROOF SUPPORTS FOR USE AT FACES IN CONJUNCTION WITH MECHANICAL LOADING

BY

EDWARD THOMAS, C. H. SEELING, FRANK PERZ, AND M. V. HANSEN

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CONTROL OF ROOF AND PREVENTION OF ACCIDENTS FROM FALLS OF ROCK AND COAL[1]

Suggested Roof Supports for Use at Faces in Conjunction with Mechanical Loading

By Edward Thomas,[2] C. H. Seeling,[3] Frank Perz,[4] and M. V. Hansen[5]

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INTRODUCTION

This is the second of a series of information circulars dealing with the control of roof and the prevention of accidents from falls of rock and coal. Their purpose is to focus the attention of the coal-mining industry on the most-common source of fatalities and injuries in mining coal and to disseminate information that may be helpful in combating the roof-fall hazard. Inasmuch as approximately 85 percent of roof-fall accidents occur in the face region, the importance of analyzing the accident-producing aspects of methods of roof support at the face - or lack of method - cannot be overemphasized.

This circular is not intended to be an exhaustive treatise on methods of roof support in face regions but rather is a description of several methods of support that appear to offer distinct advantages with respect to safety and efficient operation.

GENERAL

In many mines the simple safety post offers effective protection at the face with hand loading; after mechanical loading equipment is installed, however, safety posts may interfere with the efficiency of the equipment, and their effectiveness may be destroyed because of frequent accidental dislodgment. Too often the result is that either the safety posts are eliminated or they are used only when an official is present. Consequently, the more-progressive mining companies are continually searching for improved types of roof support that will give maximum protection and at the same time offer minimum interference with the preparation and loading of coal.

The ideal roof support at the working face should have the following characteristics:

1. It should afford unfailing protection for the mining- and loading-machine operators and helpers and others who must work near the face.

2. It should be so constructed that it does not itself present a hazard through accidental dislodgment, as by a loading head or conveyor boom.

3. If legs are used, they should be so placed that they do not interfere with a loading machine "cleaning up" the face; that is, it should not be necessary for a hand shoveler to work between the loading machine and the face.

4. If a temporary support is used, it should be one that can be easily handled and quickly installed.

5. Its cost should not be excessive.

Supports for use at the face in mechanized operations may be classed as: (1) Those that are temporary and will be replaced by permanent supports after the face advances, and (2) those that are permanent supports. In many instances supports intended to be temporary become permanent and, conversely, supports that were meant to be permanent must be replaced because of unforeseen difficulties. The extent to which this distinction is made by mining companies is governed by the type of support in use, the uniformity of roof conditions, and the conformance with timbering standards.

TEMPORARY SUPPORTS EMPLOYING LEGS

In several districts the practice of carrying two to five sets of temporary cross bars has been adopted; that is, with each cut of coal the set farthest from the face is dismantled and reset at the face, but if the roof appears to require permanent support a permanent cross bar is erected before the temporary one is moved to the face. Temporary bars are rotated, regardless of the appearance of the roof, for the purpose of protecting against undetectable weaknesses until the face has advanced far enough to assure stability of the roof.

Several combinations of legs and bars are in use for these temporary cross-bar sets: The conventional three-piece cross-bar set of hewed or sawed timber; a sawed wooden bar supported by two or more jacks; a structural shape - usually the H-beam section is preferred - of steel or one of the lighter aluminum-magnesium alloys supported by jacks; and steel rail supported by either wooden posts or jacks. The structural shape of lightweight alloy, supported by more than two jacks, gives a high degree of protection; such a set is easy to erect and offers minimum interference with operation of face equipment. However, in narrow work where only two legs or jacks are used, none of the supports mentioned will permit a loading machine to clean up the face without danger of disturbing the legs or jacks.

Pin-Jack Method

A method of support developed in the 6- to 10-foot Pittsburgh coal bed in northern West Virginia utilizes 5- by 7-inch wooden cross bars supported by screw jacks, which in turn are supported by round steel pins inserted in holes in the ribs as shown in figures 1 and 3.

The holes, which are 1-7/8 inches in diameter, are drilled opposite each other to a depth of 18 to 20 inches in each rib at a point about 5 feet below the roof, allowing 2 to 5 feet of clearance above the floor. A round steel pin 1-5/8 inches in diameter and 18 inches long, with a collar 3 inches from one end, is inserted in each hole so that 3 inches of the pin extends outside the hole. The ordinary procedure is to drill the holes for the pins at the same time that the holes for blasting are drilled in the face. A hand-held electric drill equipped with a short auger is used for this purpose.

Costs (January 1948): The pins are made locally and cost approximately $1 each, including material and labor; jacks, according to the specifications shown in figure 3, cost approximately $7 each. Each working place is provided with 10 pins, 10 jacks, 5 sawed wooden cross bars, and an ample supply of wooden wedges and blocks. The total investment is approximately $100 per working place. Inasmuch as all this material is in constant use, it is seldom misplaced or lost.

Ordinary timberjacks have been used with the pin-jack method to permit top-cutting machines to make a horizontal cut and maintain the proper thickness of head coal and to provide roof support above turn-outs and side-cuts. These timberjacks support a structure composed of three steel H-beams acting as carrying or bridge bars and three wooden cross bars, as shown in figures 2 and 4. Turn-outs can thus be started at an angle of 40° with an entry and attain 90° with it after the third cut.

The main supports consist of three 6-inch, 15.5-pound steel H-beams. The framing, indicated in figure 4, can be accomplished by cutting the flanges or webs and reinforcing the weakened sections with plates welded to them. It is estimated that the material and shop work for the H-beams used in each turn-out set will cost approximately $40. Two man-hours is required to erect a set underground with a three-man crew.

Mining companies using this method of timbering claim the following advantages:

1. Any number of supports may be erected without restricting the working space of men or machines.

2. The workmen approve the method, recognize its safety features, and therefore cooperate in following it.

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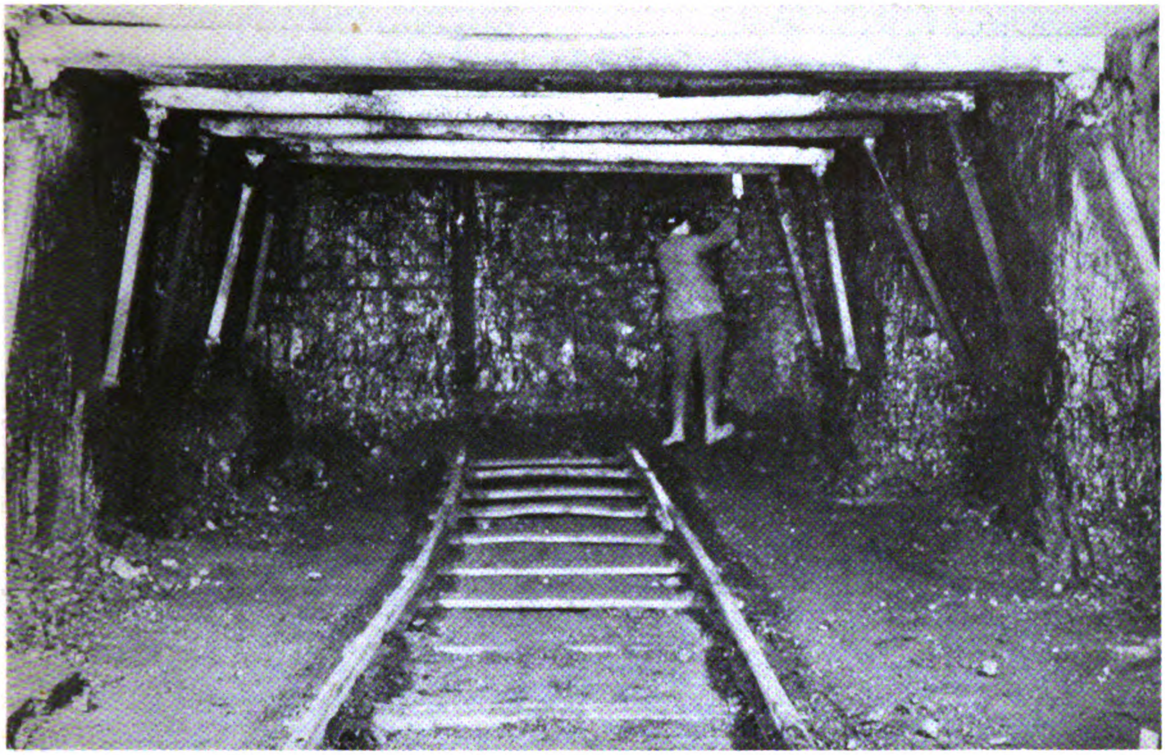

Figure 1. - Pin-jack method; roof at face of room supported by five cross bars.

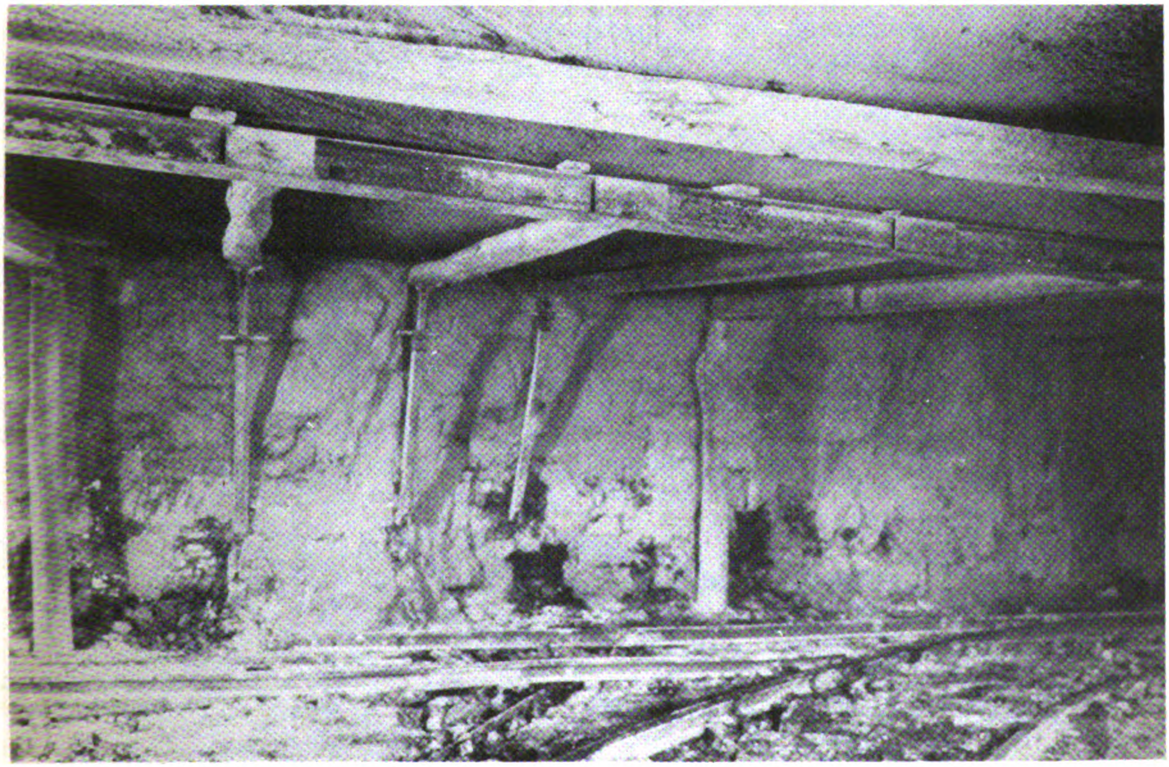

Figure 2. - Pin-jack method; support at turn-out shows spreader bar with welded web reinforcement.

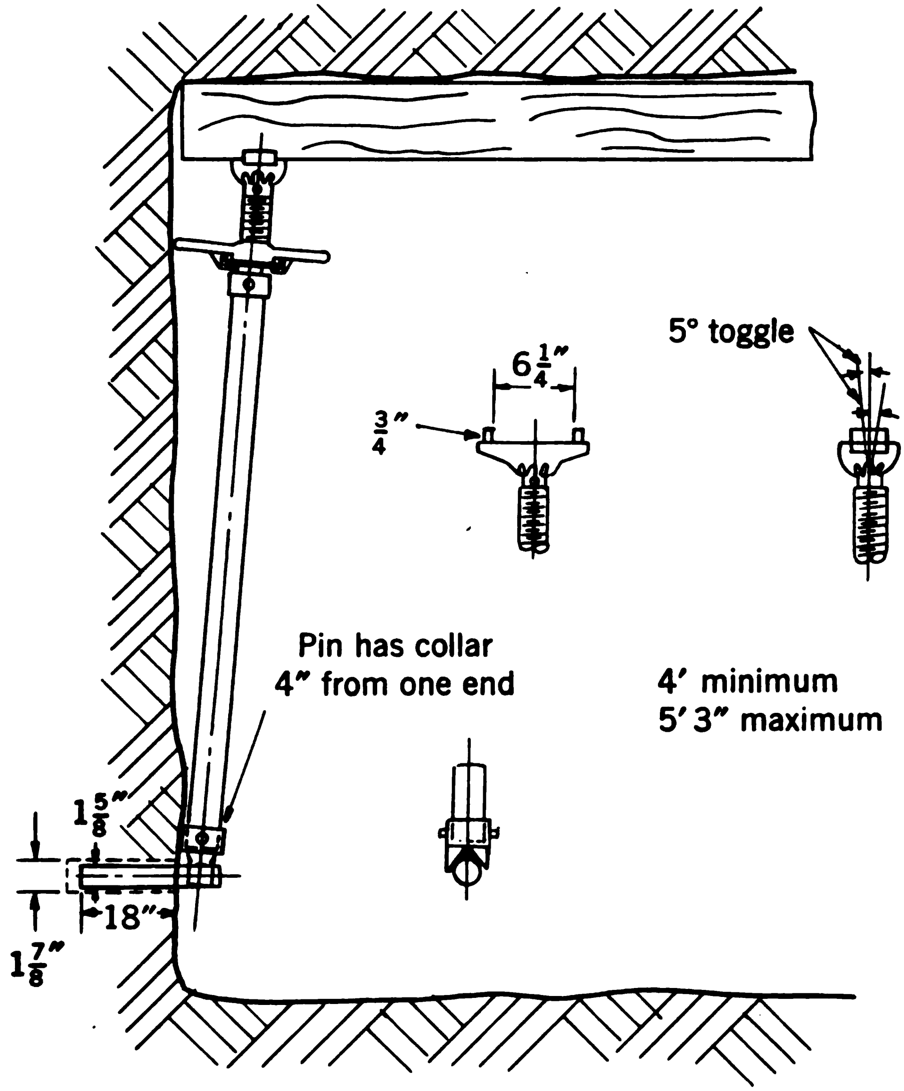

Figure 3. - Pin-jack method.

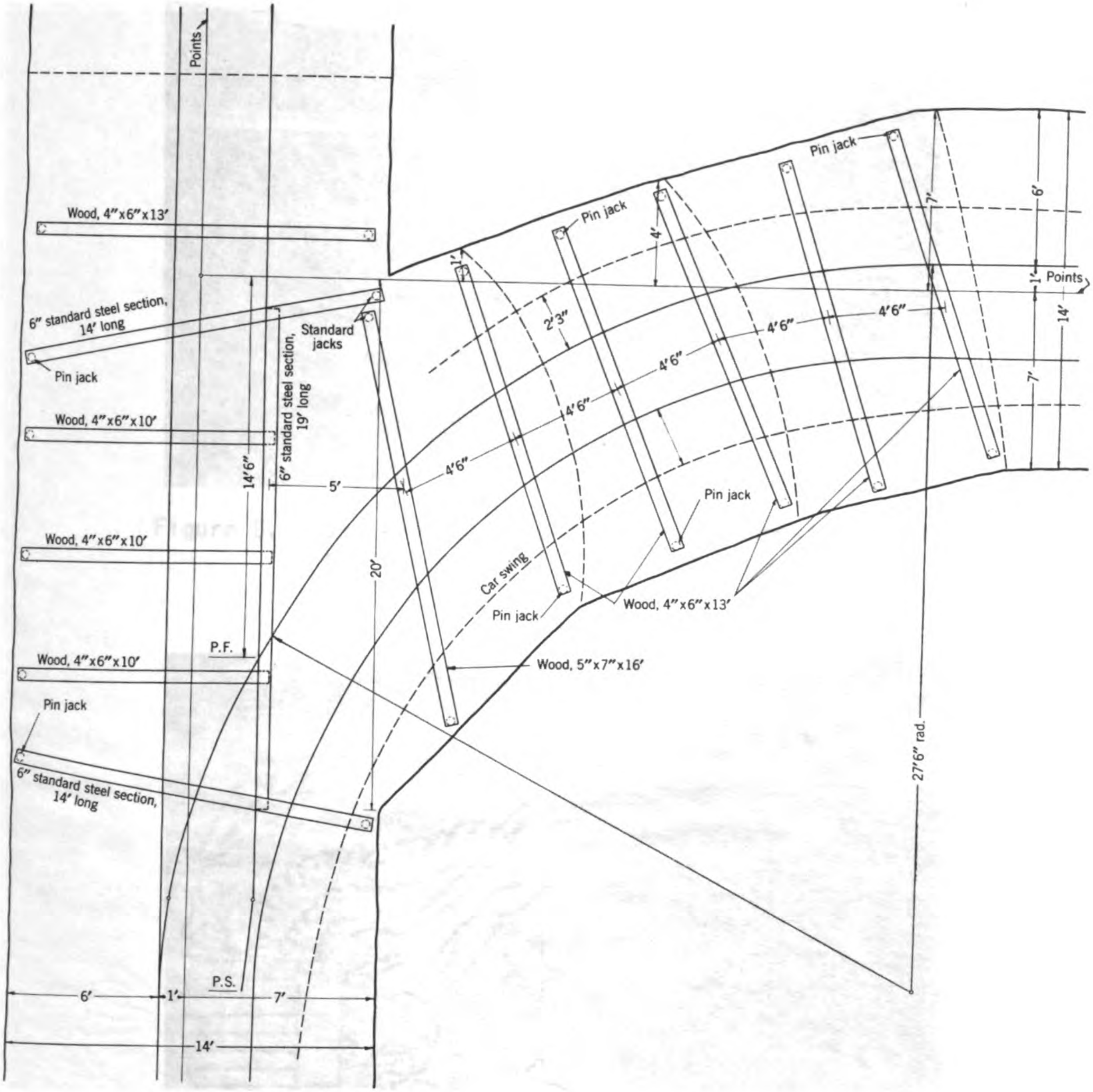

Figure 4. - Pin-jack method, showing turn-out supports.

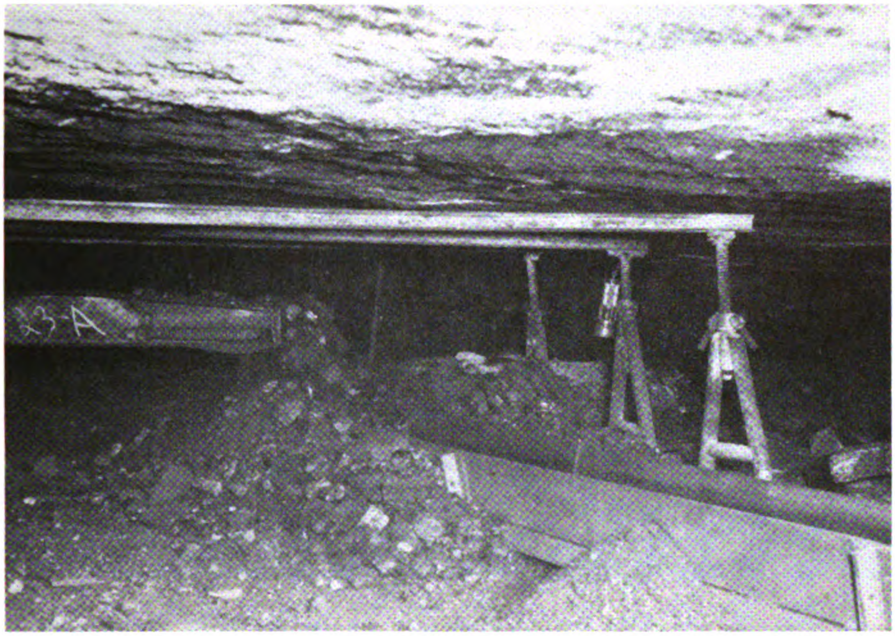

Figure 5. - Skid-mounted supports; roof supported at face of room by steel-rail cross bars on skid-mounted jacks.

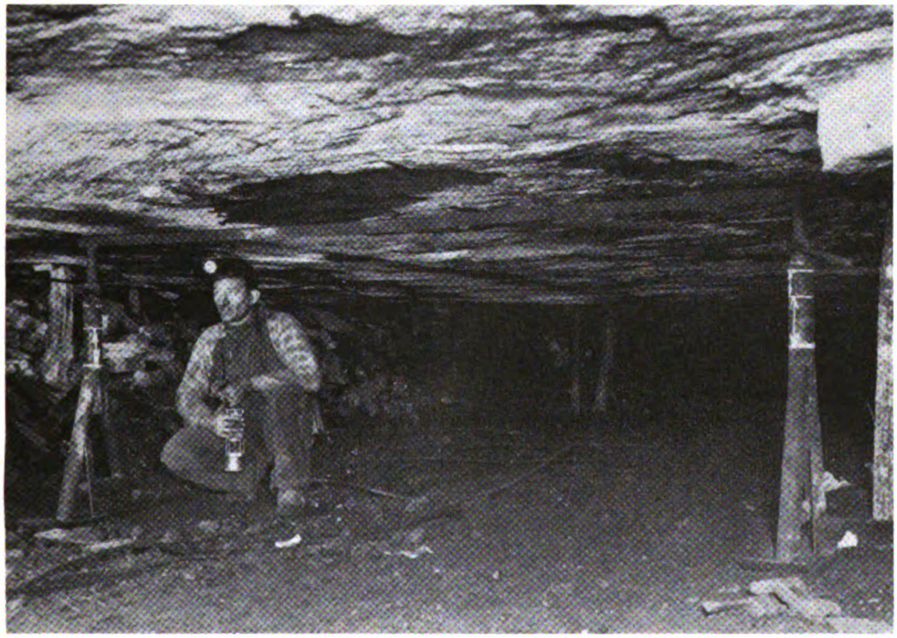

Figure 6. - Skid-mounted supports, showing collars; these may be removed for low coal.

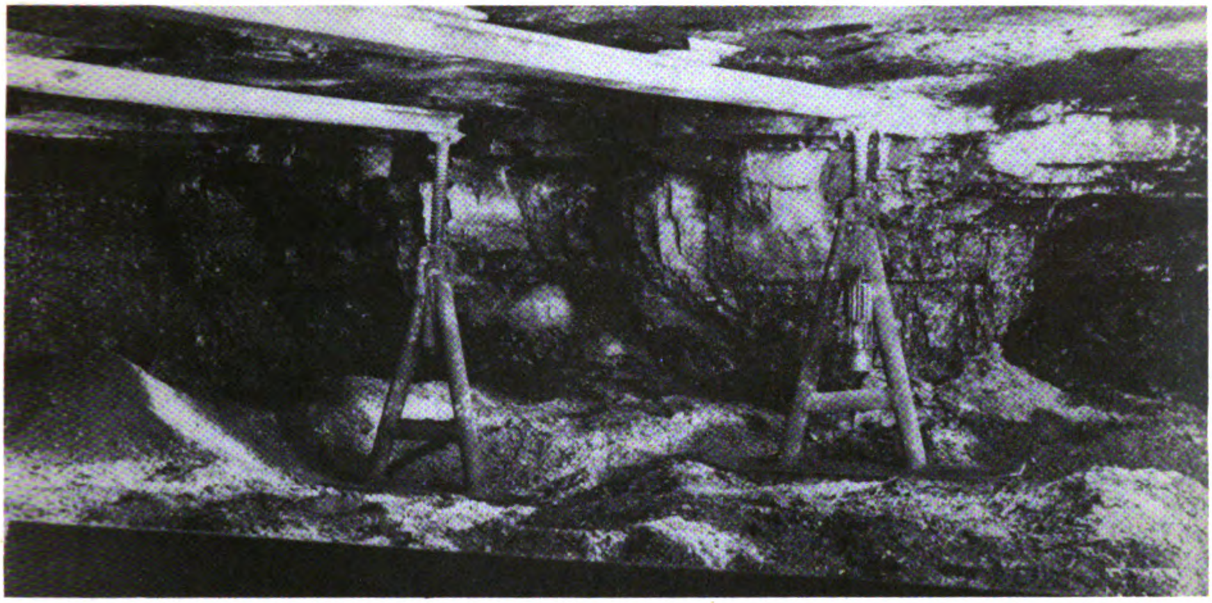

Figure 7. - Skid-mounted supports; screws attached to bars.

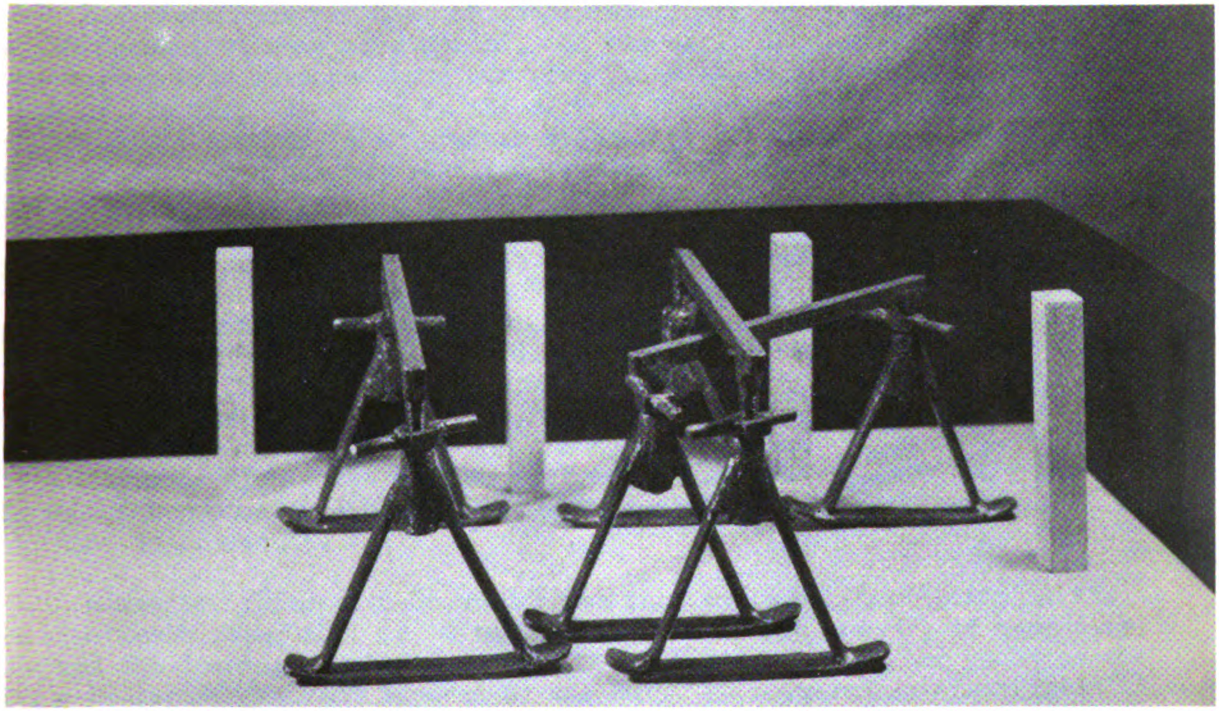

Figure 8. - Skid-mounted supports, showing method of skidding lowered cross bar diagonally under other bars to new position at the face.

3. As compared with the use of the conventional three-piece wooden set (provided none of the wooden sets is to remain for permanent timbering), the saving in time required for erection and dismantling sets is estimated to be 50 percent.

4. The "clean-up" time for the loading machine is reduced by an estimated 25 percent.

5. All the coal at the face and sides, including that thrown back from "scrap cuts," can be cleaned up by the machine without having to be shoveled by hand from behind or between legs.

6. The loading is speeded up; the loading machine can be operated at full speed without fear of dislodging timbers. It is claimed that none of the jacks or pins has been dislodged by the loading machines since the method was adopted.

Skid-Mounted Supports

Figures 5 and 7 illustrate a type of roof support developed by Anthony Shacikoski[6] and used in the mines of the Leechburg Mining Co. in Armstrong County, Pa.

The cross bars are made of steel rail of suitable length and weight to which jackscrews have been welded. In the early development of this support the screws were attached to a bar with bolts through straps welded to the base of the rail, as shown by the jack on the right in figure 7. It was found later, however, that greater stability and strength, as well as increased ease of handling, resulted from welding the screws to the base of the rail.

The base of each jackscrew is a triangular frame of steel pipe welded to a skid plate and having at the apex a bottomless vertical section of pipe of proper diameter to admit the stem of the screw. The height of the jack may be changed to suit local conditions by adding or removing loose collars below the nut of the screw. Examples of these collars are marked by the arrows in figure 6.

Figure 6 also shows a "boney" bar of angle iron designed to secure the brows of top bone in crosscut openings, where the bone is taken down in rooms but not in crosscuts.

Normally, three skid-mounted cross bars are used in rotation at the face of each room; that is, after each cut is loaded out or, if necessary, before the loading is completed, the outby bar is removed and reset at the face to secure the roof exposed by the cut. An outstanding advantage claimed for this method is that the cross bar and jacks can be moved on the skids without dismantling them. Figure 8 illustrates, by means of models, the operation of skidding a lowered cross bar diagonally under the other bars to its new position at the face, where it can be readily secured.

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[6] Superintendent, Leechburg Mining Co., Avonmore, Pa.

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Figure 9 shows a special modification of the skid-mounted roof support; such a method is used with a roof condition so dangerous as to require forepoling or some other means of immediate and constant support as soon as the roof is exposed at the face. Four skid-mounted steel cross-bar sets are utilized to support four transverse wooden cross bars, and each steel cross bar projects like a forepole about one-third or one-quarter of its length beyond the inby jackscrew. The steel bars are set parallel to the direction of the room, not across it. As the room advances, the two steel bars in the center are loosened and moved forward; then the bars nearest each rib are advanced alternately so as to provide support for successive wooden cross bars at the face. In figure 9 the two center bars have just been moved forward to secure the inby cross bar.

The next step is to set permanent posts or legs under the ends of the fourth cross bar from the face and then loosen and advance the steel bars nearest the ribs.

Although modifications and improvements are still being made, the mine management expresses great satisfaction with the skid-mounted roof supports and the results obtained. It is difficult, if not impossible, to estimate the number of accidents prevented or lives saved by any given safety device or method; however, the management reported four instances, within 18 months after the adoption of the skid-mounted supports, in which large pieces of rock dropped from the roof over face areas occupied by one or more men, who were saved from injury by the steel cross bars. In several instances it was necessary to blast the rock before it could be removed and production resumed.

TIMBERING MACHINES

During the past 20 years several timbering machines have been designed and constructed locally to expedite the rapid framing and construction of wooden cross bars. These machines are usually portable and are equipped with an adjustable circular saw for cutting timber and a device for supporting the cross bar against the roof while the legs are being set in place. (See fig. 10.)

TEMPORARY LEGLESS SUPPORTS

The legless-type of cross bar is the most-desirable roof support, with respect to both operation and safety, for protection at the face and for permanent support over roadways because it has no legs to become dislodged. It affords maximum lateral clearance and presents no obstacles to continuous mechanical loading or cutting. Legless supports usually cannot be justified for temporary use except under unusual circumstances because they require the use of special equipment and methods of construction that may interfere with the cycle of operations.

Expansion-Bolt Method

At the No. 7 mine of the Consolidated Coal Co., Staunton, Ill., expansion bolts with steel plates are used to support a very weak immediate roof

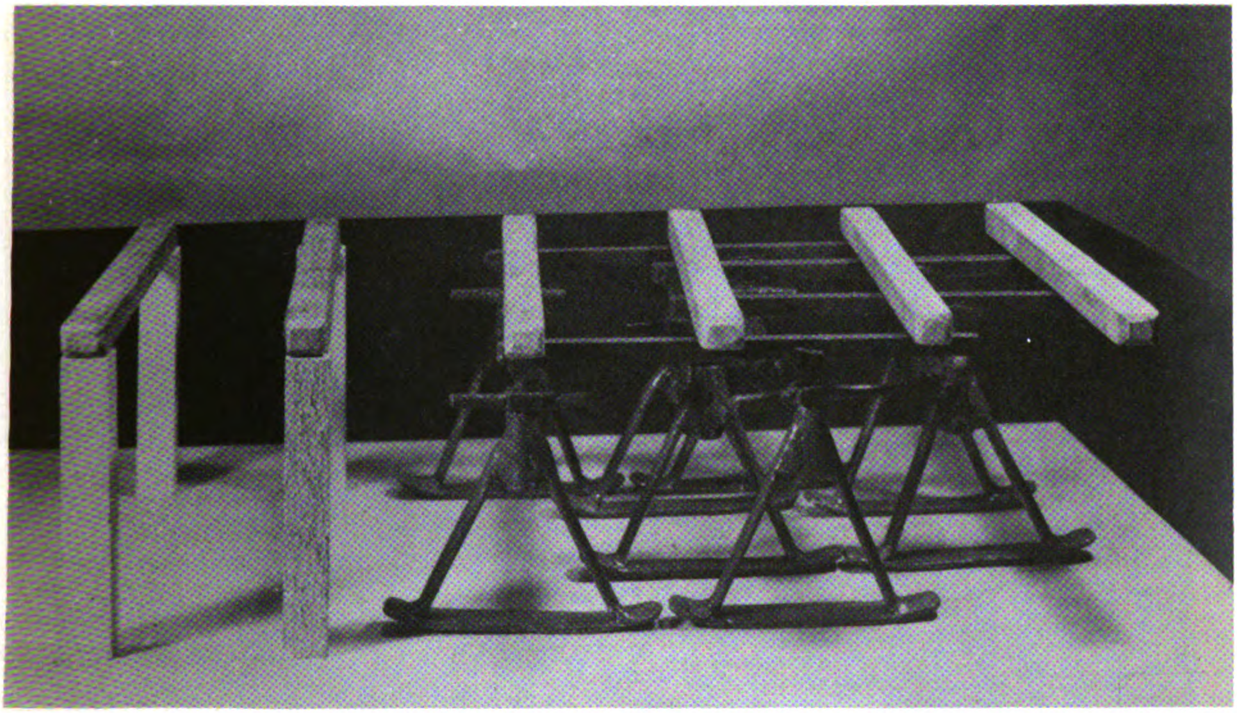

Figure 9. - Skid-mounted supports; used where roof conditions require forepoling.

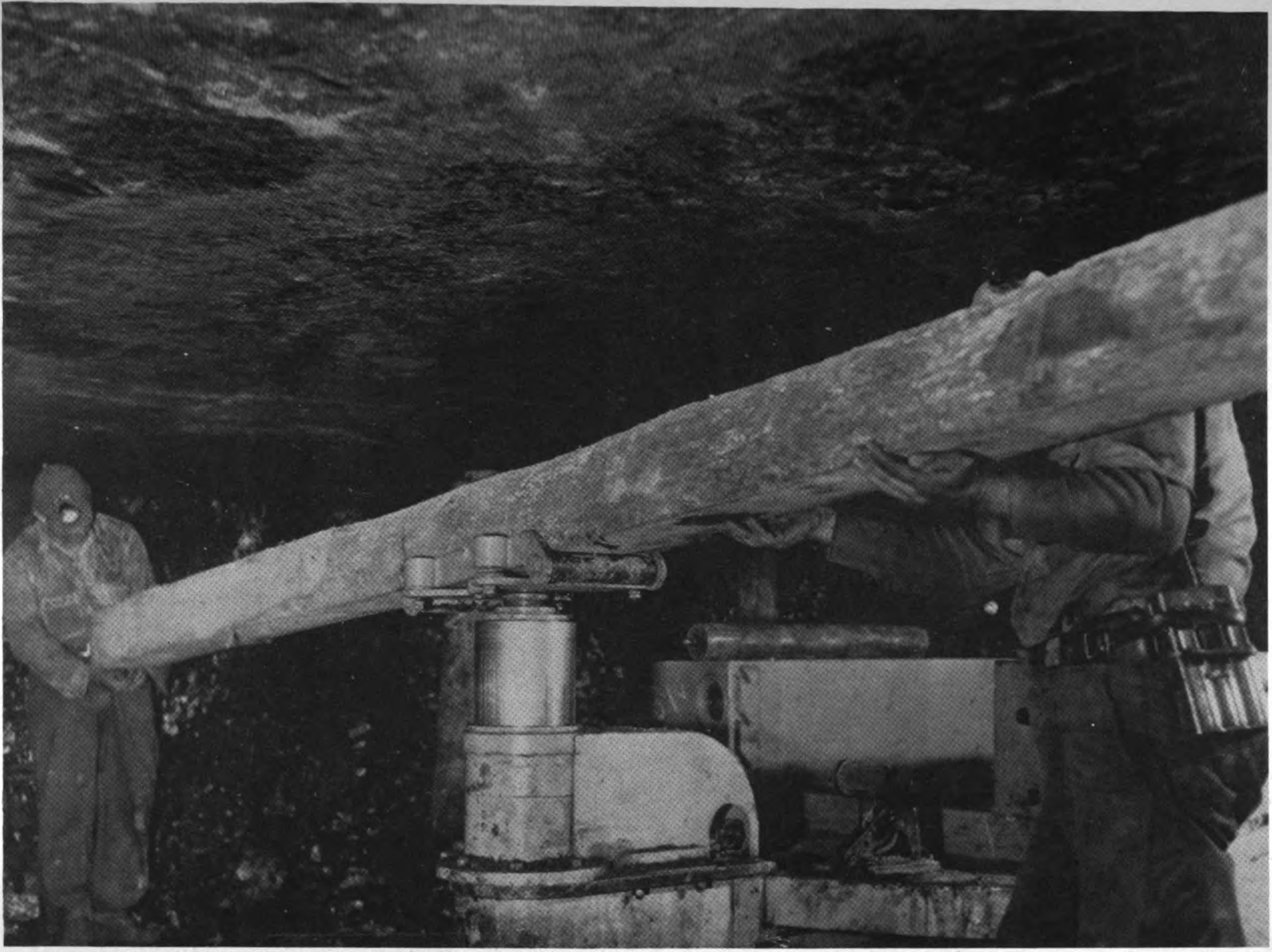

Figure 10. - Timbering machine.

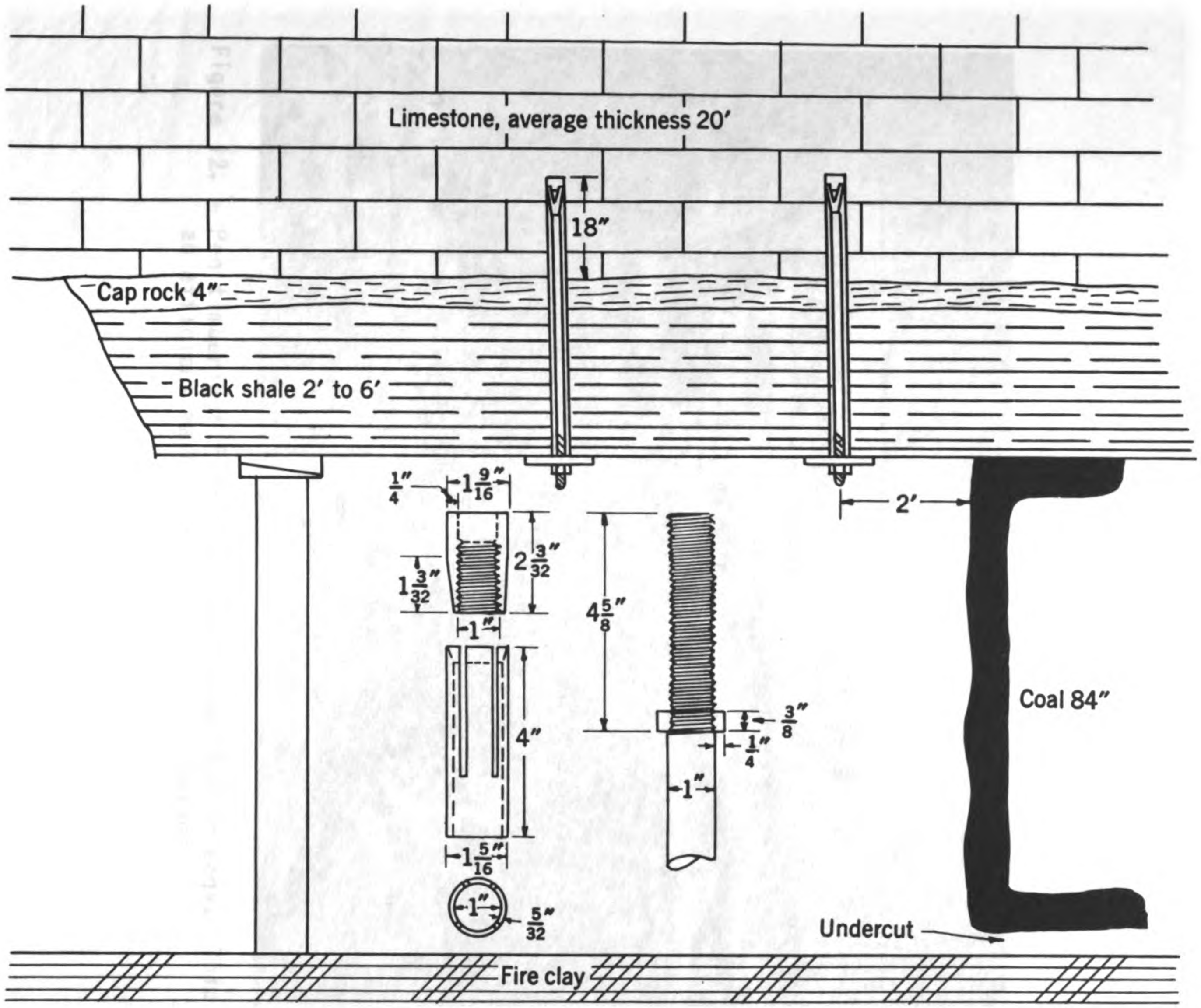

Figure 11. - Expansion-bolt method.

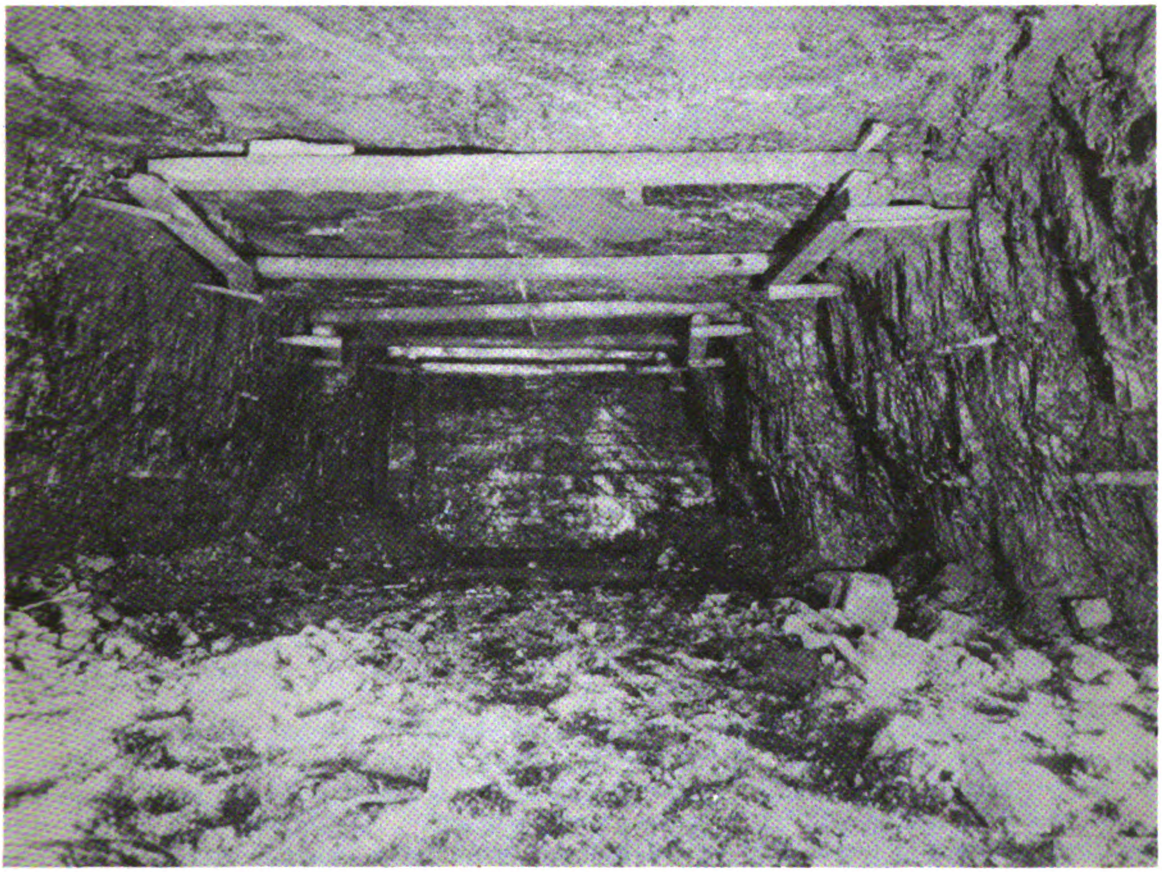

Figure 12. - Peg timbering; five cross bars supported on pegs. This is an efficient method with shuttle-car haulage.

by anchoring it to a strong main roof. An immediate roof of weak clod, ranging from 2 to 4 feet in thickness, either falls with the coal during blasting or, when it can be held with safety posts, presents a constant hazard to shovelers at the face. The stratum overlying the clod is a massive limestone averaging 20 feet in thickness.

Vertical holes are drilled in the roof 3 to 6 feet deep, depending upon the thickness of the clod, and extend approximately 18 inches into the limestone. Rods 1 inch in diameter, fitted with expansion shells, are wedged into the limestone at the backs of the holes by rotating the rods, as shown in figure 11. Bearing surface is provided for the hexagonal nut on the threaded end of the rod by a steel plate, 3/4 inch thick, 8 inches wide, and 12 inches long.

Ordinarily the hangers are spaced approximately 3 feet apart and may be placed as close as 2 feet to the face. The vertical holes are drilled with a short auger while the face is being prepared for blasting. The hangers are not dislodged by blasting. After the face has been advanced several cuts the clod is barred or blasted down, and the hangers are recovered for reuse.

Peg Timbering

Peg timbering is a legless method of roof support that has met with considerable success for temporary support at the face. By this method wooden cross bars are supported by steel pegs inserted in holes drilled in the coal ribs near the roof, as shown in figure 12.

Obviously this type of support can be applied only to structurally firm beds of coal where there is little likelihood of large slabs of rock separating from the roof.

Holes 1-3/4 inches in diameter on 5-foot centers are drilled in the ribs 9 inches below the roof and 18 inches deep before the coal is cut. The pegs are made from 30-inch lengths of 30-pound scrap-steel rails forged round on one end to fit the holes. The pegs are inserted in six holes in each rib, and 5- by 7-inch wooden mine ties, supported by the pegs, serve as stringers. Each pair of cross bars is thus supported on each end by one stringer and two pegs.

As the face advances, the two outby bars and their supporting pegs are recovered and moved forward. Before temporary cross bars are removed, timber-jack safety posts are set for temporary protection before work is done between the face and the cross bar nearest the face. Permanent timbers are erected as needed.

PERMANENT LEGLESS SUPPORTS

Hitch Timbering

The most-widely used types of legless support for face regions are those in which a wooden or steel cross bar is supported in hitches drilled or cut into the coal rib, as shown in figure 13. Usually the hitches are made with a top-cutting machine at the same time that the face is cut. The limitations of this method are largely the same as those of peg timbering.

The principal objection to this method is that the diameter of the cutter-bar swing is usually greater than the width of the roadway and the hitch must be cut at an angle. One company uses a special cutting machine with a short cutter bar to drill the hitches; otherwise, the result usually is that an almost continuous groove is cut in each rib, which has the effect of increasing the span of exposed roof that must be supported.

Suspension Supports

The basic concept of suspension-type supports was developed over the past 20 years in the mines of the St. Joseph Lead Co.[7] in southeastern Missouri. The principle is to reinforce roof rock by means of steel rods anchored at points where the rock is least likely to be altered by stresses set up by the mining operation itself.

An approximate graphic analysis of the stresses acting in the roof rock above a mine opening, based on the assumption that a bed of coal is uniformly loaded by the pressure of the overlying strata (approximately 1 pound per square inch for each foot of depth), is shown in figure 14.

If the pillars on each side of the roadway are large enough to withstand the load, a roughly semicircular arch is formed; this is shown by the broken line in figure 14. On the outside of this arch line the stresses are predominantly in compression; on the inside they are predominantly in tension. Inasmuch as rocks ordinarily have several times as much strength in compression as they have in tension, only the material within the arch will require immediate support if it is not self-sustaining.

In bedded strata where there is no cementation between the beds or where the cementing material has been altered, each stratum within the arch line acts as an individual beam. Before each beam fails it must sag along its length, and the maximum sag will be at or near the middle of the span even though failure may occur at the ribs. The amount of this sag depends upon the modulus of elasticity and the length and thickness of the beam. If enough resistance is properly distributed throughout the length of the beam so as to prevent the sag that must occur before failure, no concern need be felt about vertical load.

Several companies have installed or are about to install roof supports on an experimental basis, using methods similar to those shown in figures 15 and 16. Holes 1-1/8 inches in diameter are drilled 7-1/2 feet in the roof at an angle of 45°, and 1-inch-diameter rods slotted at the back and threaded at the collar are driven onto the wedge at the back of the hole by means of a

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[7] Weigel, W. W., Channel Irons for Roof Control: Eng. and Min. Jour., vol. 144, No. 5, May 1943, pp. 70-72.

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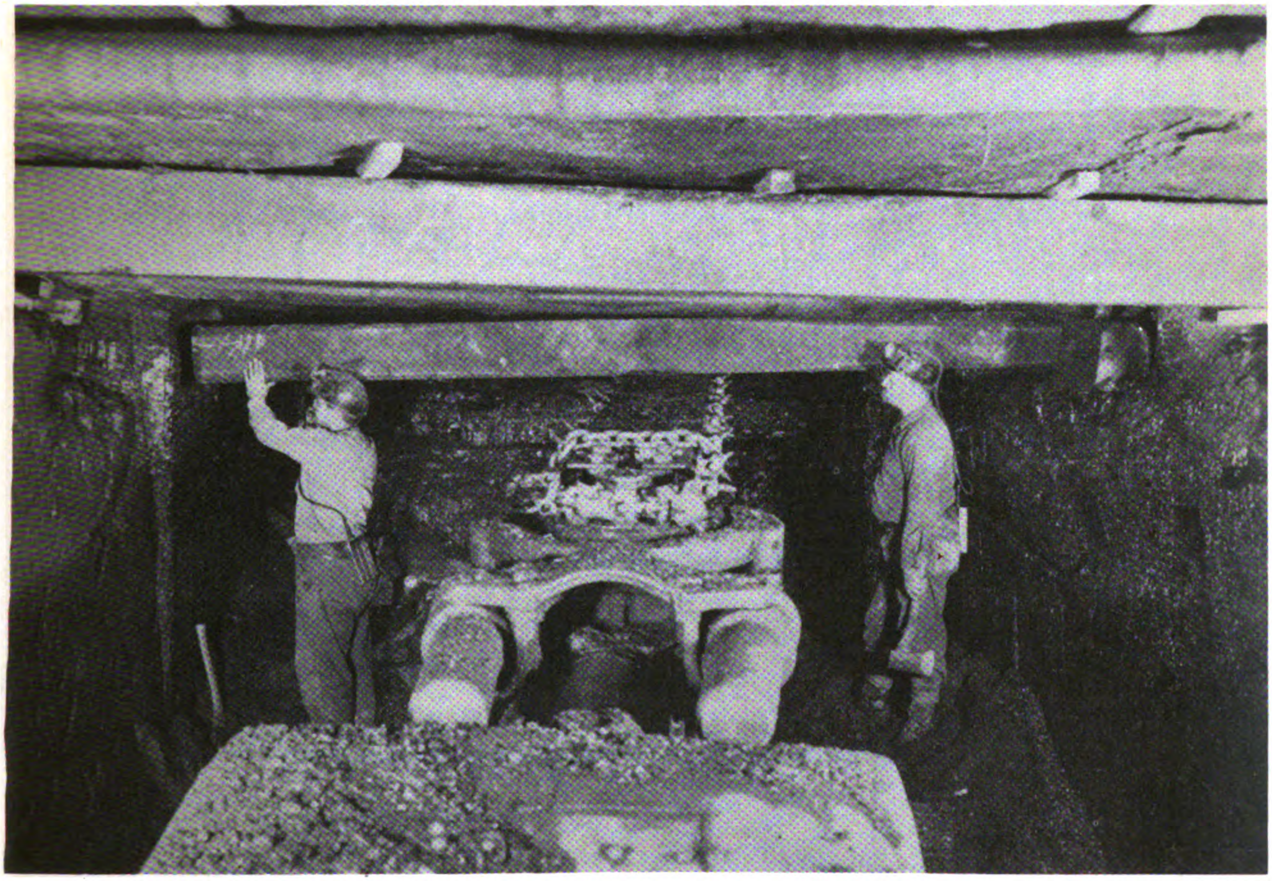


Figure 13. - Hitch timbering.

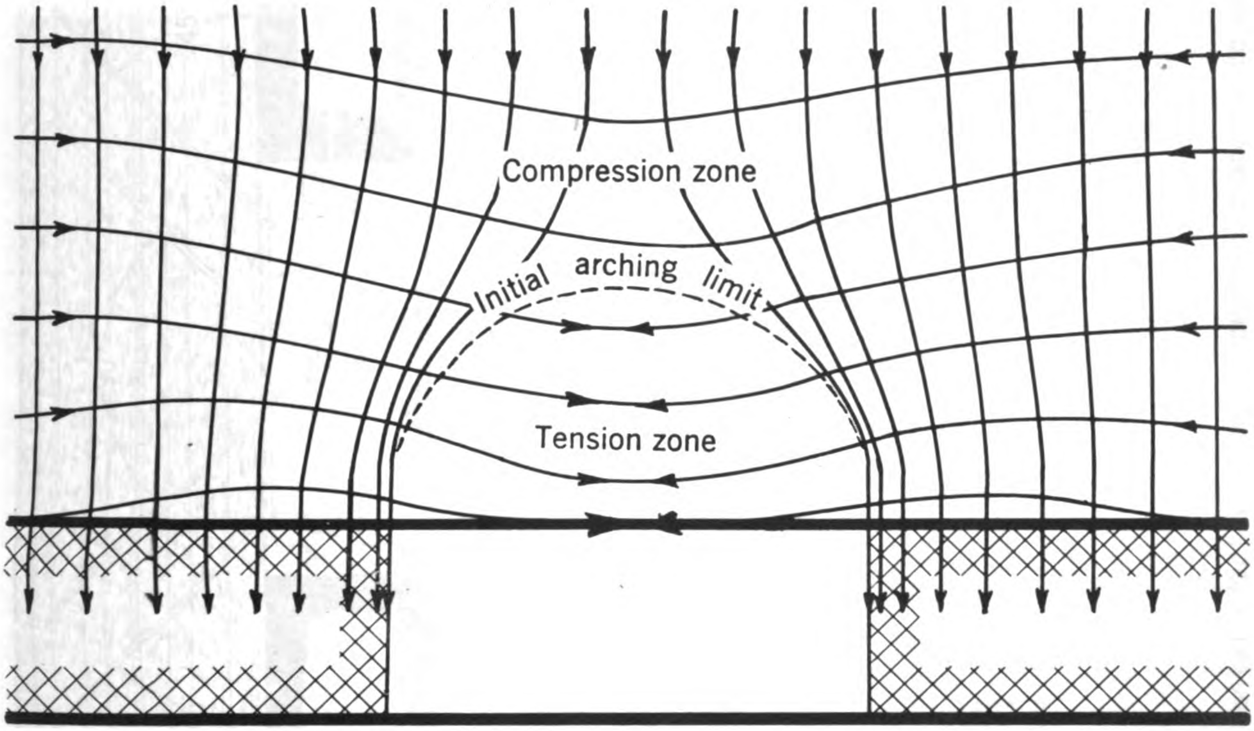
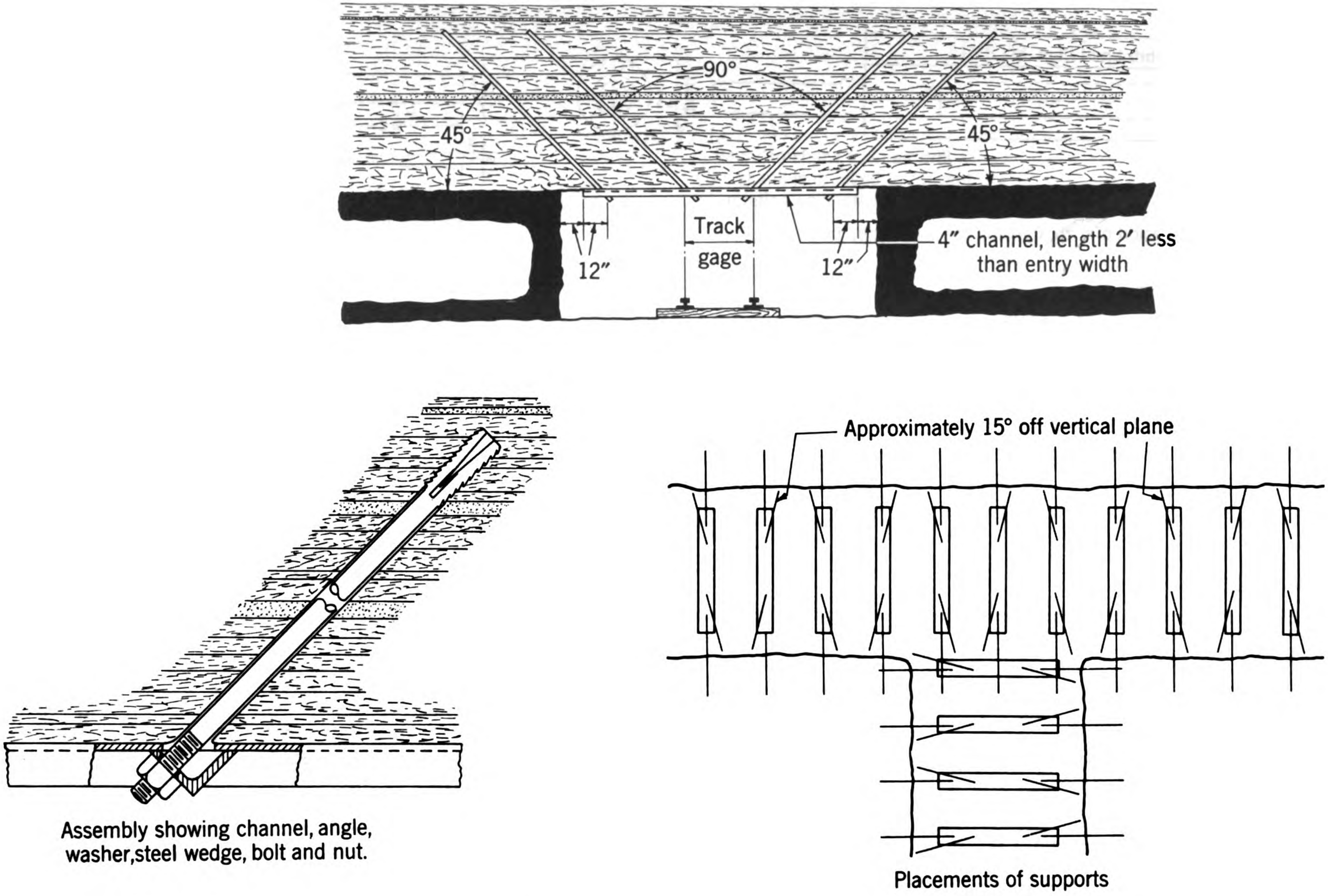


Figure 14. - Approximate distribution of stresses above an untimbered opening.


90°
45°
45°
Track gage
12″
12″
4″ channel, length 2′ less than entry width
Approximately 15° off vertical plane

Assembly showing channel, angle, washer, steel wedge, bolt and nut.

Placements of supports

Figure 15. - Experimental adaptation of suspension supports to coal-mine roadways.

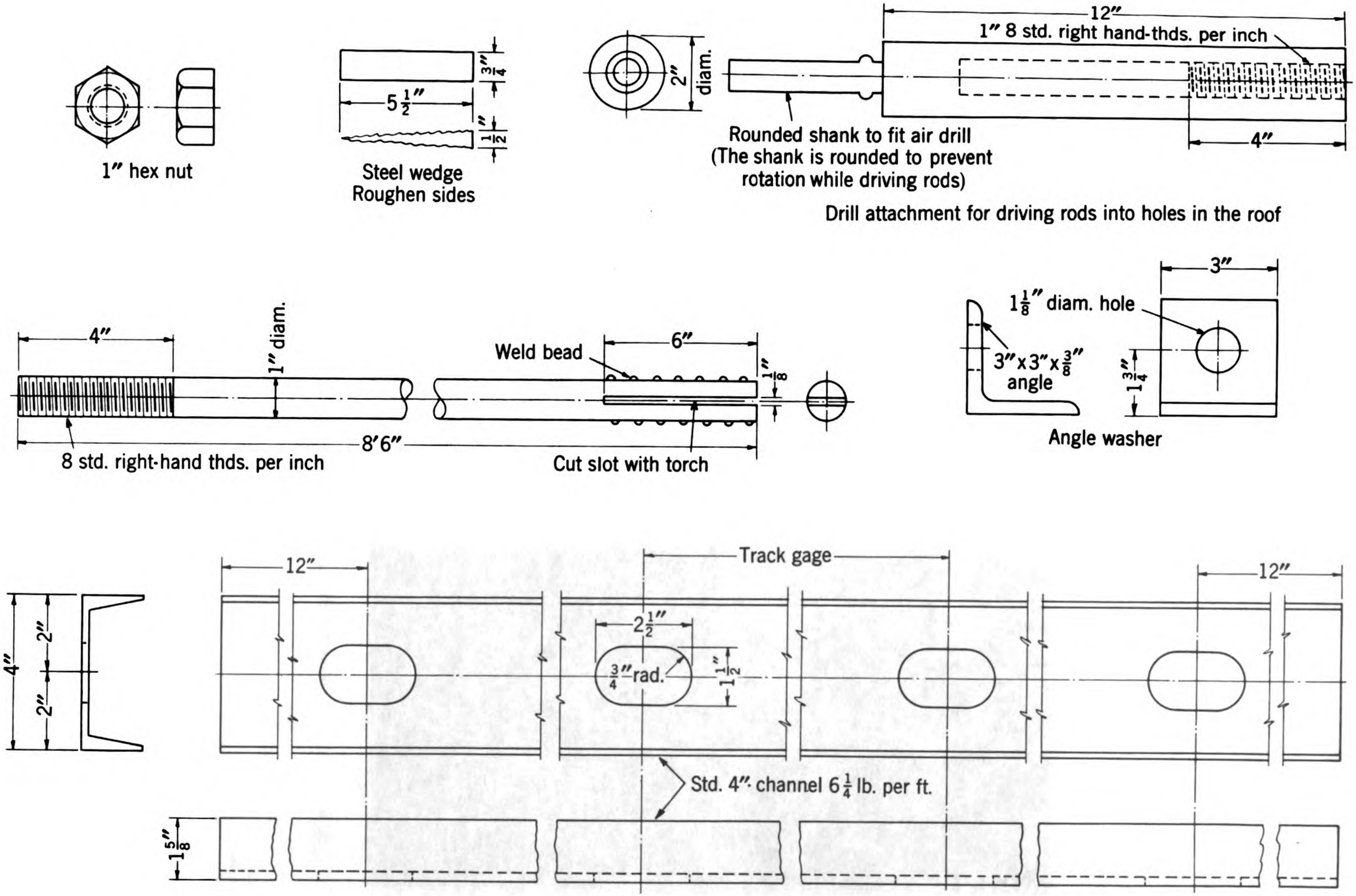

1" hex nut
5 1/2"
3/4"
1/2"
Steel wedge
Roughen sides
2"
diam.
12"
1" 8 std. right hand-thds. per inch
4"
Rounded shank to fit air drill
(The shank is rounded to prevent
rotation while driving rods)
Drill attachment for driving rods into holes in the roof
4"
1" diam.
Weld bead
6"
1/8"
8'6"
8 std. right-hand thds. per inch
Cut slot with torch
3"
1 1/8" diam. hole
3"x3"x3/8"
angle
1 3/4"
Angle washer
Track gage
12"
12"
4"
2"
2"
2 1/2"
3/4" rad.
1 1/2"
Std. 4" channel 6 1/4 lb. per ft.
1 5/8"

Figure 16. - Details of experimental adaptation of suspension supports.

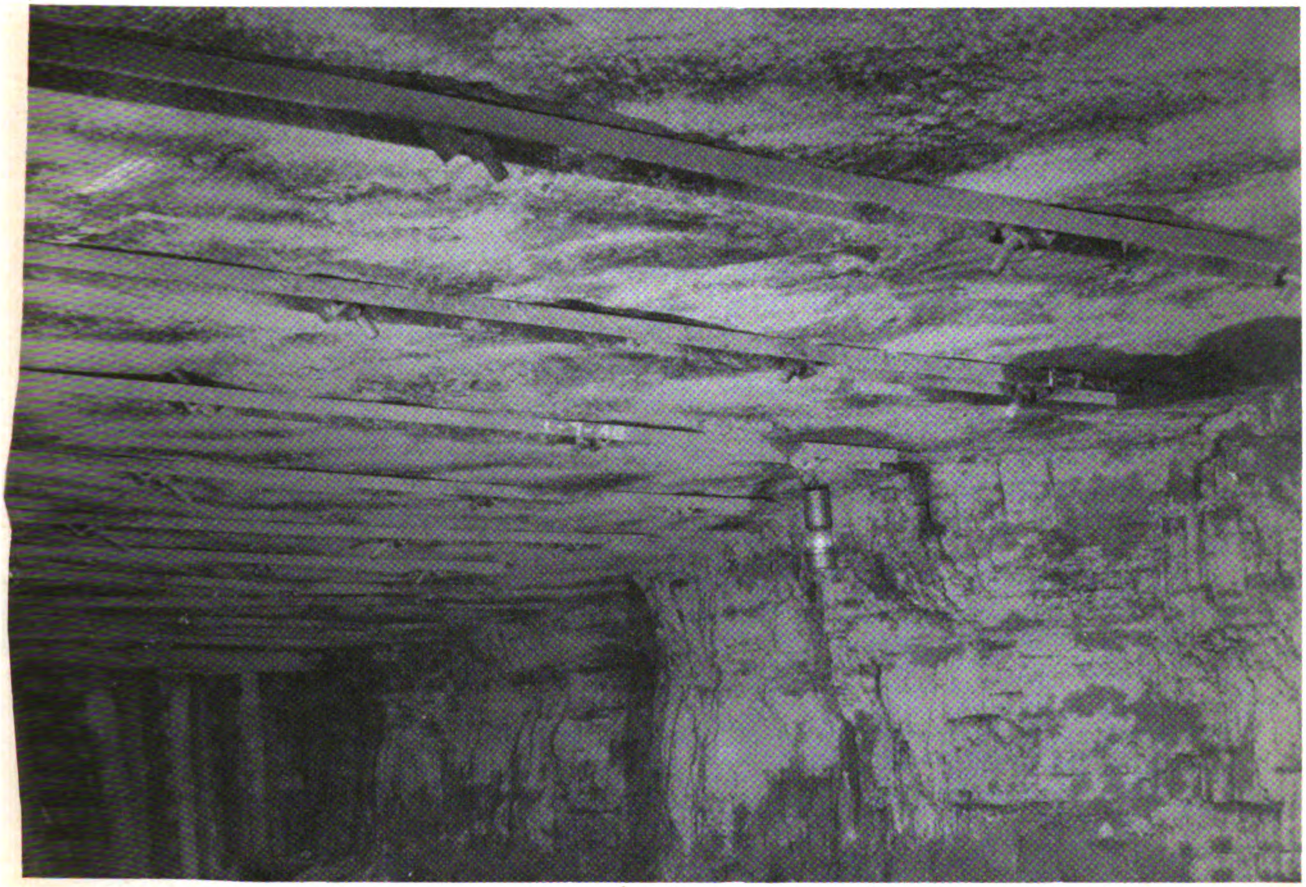


Figure 17. - Experimental installation of suspension supports in a coal mine.

pneumatic hammer. A 4-inch channel with 1-foot clearance on each side of the roadway is used to give lateral support and rigidity to four rods placed as shown. Assuming that a mine track is in the middle of the roadway, the two middle rods are lined directly over the rails (it is believed that the hazard from protruding bolt ends will be the minimum in this position), and the two end rods are placed reasonably close to the ribs to insure maximum support in the solid rock directly above the pillars. Figure 17 shows an experimental installation of such supports in a coal mine.

The correct spacing of the sets must be gained by experience. It is recommended that in experimental installations the spacing formerly used for erection of cross bars be followed.

The following points should be considered before experimenting with or adopting this method of support.

1. By using carbide-alloy bits the holes may be bored successfully by means of electric drills. However, experience in southeastern Missouri has proved that the rods cannot be secured properly unless a percussion tool is used to drive the rod against the wedge at the back of the hole. For this reason, it may be difficult to coördinate this method of roof support in its present stage of development with highly mechanized operations because compressed-air lines are not generally installed in bituminous coal mines. The use of pneumatic equipment would therefore require portable air compressors; in shifting them about the interference with other mining operations would be objectionable.

2. For maximum effectiveness the sets should be installed as close as possible to advancing faces so that ample support is applied before the strata begin to sag.

3. A "stoper" drill should be used for drilling the holes. In shales and sandstones an "up" hole 8 feet long can be drilled in 5 to 10 minutes. Considerable time can also be saved if a power-driven wrench instead of a hand wrench is used to tighten the nuts.

CONCLUSION

In modern mechanized mines working faces advance too rapidly to depend upon the judgment of individuals as to whether the roof is sound. In too many instances roof that appeared to be safe and self-supporting when inspected became dangerous when the face advanced a few feet, and workers at the face - intent upon the production of coal - were not aware of a developing hazard until someone was injured or killed. Mines that have the fewest roof-fall accidents are those in which personal judgment of the soundness of roof is eliminated by supporting the roof in face regions, regardless of its character and appearance. Therefore, at every mechanized mine roof conditions should be studied thoroughly, and a systematic method of support should be adopted to give maximum safety for the conditions encountered. Such procedure is the best insurance against roof-fall accidents at the face.